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The Role of Sentence Context in the Resolution of the Word to during Reading

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Abstract

In English, the word 'to' functions as a preposition (e.g., 'to the store') and also as part of an infinitive (e.g., 'to go'). Two experiments investigated how the word 'to' is resolved by fluent readers. Readers comprehended sentences that contained the word 'to' preceded by sentence context that either did or did not disambiguate the role of the word 'to' in the sentence. The word 'to' was followed by sentence context that disambiguated the word 'to' as a preposition or as part of an infinitive. Processing load was assessed immediately after ambiguous word 'to' was read (Experiment 1) and immediately after the disambiguating word was read (Experiment 2) using a uni-modal, dual task reading technique used previously by Clifton, Frazier, and Connine (1985). The results indicated that the resolution of the word 'to' is influenced by following, but not prior, sentence context.

In English, the word 'to' may function as either a preposition or as part of an infinitive clause, as in (1a) and (1b), respectively. This type of ambiguity has been referred to as *syntactic category ambiguity* (Frazier & Rayner, 1987; also *lexical category ambiguity*, see MacDonald, 1993).

(1)	a. Joseph went *to school.*	Preposition
	b. Joseph wanted *to leave.*	Infinitive

When such an ambiguity is encountered during reading, the reader must use information from the sentence context to resolve the ambiguity. The empirical question addressed by the research described in this paper is whether prior and following sentence context is used similarly in the resolution of such ambiguities, in particular the word 'to' in English. Following sentence context may disambiguate the word 'to.' When the word following 'to' is a noun, such as 'school', comprehenders must resolve 'to' as a preposition, as in 2a. When the word following 'to' is a verb, such as 'sing', comprehenders must resolve 'to' as a being part of an infinitive, as in 2b.

(2)	a. Mary walked to school.	Preposition
	b. Mary wanted to sing.	Infinitive

Prior sentence context may also disambiguate the word 'to.' One potentially important source of disambiguating information is information about the possible usages of a preceding verb. For example, there are numerous verbs, such as 'wanted', that cannot occur with prepositional phrase (PP) complements, as in 3a, but can occur with infinitival (INF) complements, as in 3b. In contrast, there are as many verbs, such as 'walked', that can occur with prepositional phrase complements, as in 3c, but cannot occur with infinitival complements, as in 3d.

(3)	a. *John wanted the couple to the car.	PP Complement
	b. John wanted the couple to leave.	INF Complement
	c. John walked the couple to the car.	PP Complement
	d. *John walked the couple to leave.	INF Complement

The role of contextual information during ambiguity resolution has been widely debated. Frazier & Rayner's (1987) Delay Hypothesis claims that for syntactic category ambiguities, in particular, preceding contextual information is not used to inform resolution processes. According to this proposal, readers delay analysis of syntactic category ambiguities, such as the word 'to', until a word is encountered who syntactic category is unambiguous. Syntactic analysis is then postulated following *minimal attachment* or *late closure*, two principles of parsing that predict that readers will construct the least complex syntactic analysis possible or will construct an analysis incorporating the incoming materials with the most recent part of the sentence, respectively. These principles form the core of the garden path theory of sentence processing (Frazier, 1978; Frazier & Fodor, 1979; Frazier & Rayner, 1982). Contextual Information preceding the syntactic category ambiguity, although not used initially, may be used after the initial analysis is postulated (see Rayner, Carlson, & Frazier, 1983).

In contrast, a constraint satisfaction approach to ambiguity resolution (MacDonald, Pearlmutter; Seidenberg, 1994a; 1994b; Trueswell & Tanenhaus, 1994) proposes that readers rely on all types of the information available from the context to interpret each word of a sentence. In this view, there is no need to refer to initial syntactic analysis and reanalysis, for readers may consider multiple syntactic analyses in parallel and use sentential context to decide among the possibilities. In this framework, much focus has been given to the role of verb information and preferences in parsing. MacDonald (1994) proposed the Partial Activation Hypothesis which details how verb information may inform parsing decisions. When verbs are read, all possible usages of the verb are activated in parallel according to their frequency of use. The activation level or strengths are modulated by both prior sentential context and following context. There has been substantial evidence that the type of verb in preceding sentence context can influence the resolution of structural ambiguity (Garnsey,

Pearlmutter, Myers, & Lotocky, in press; Holmes, Stowe, & Cupples, 1988; MacDonald, 1994; Trueswell, Tanenhaus, & Kello, 1993; but see also Ferreira & Henderson, 1990; Kennison, 1995).

The present paper describes two experiments that investigated the role of prior and following context on the resolution of the word 'to.' The predictions of the delay hypothesis and constraint satisfaction were contrasted. Two factors were manipulated: (1) type of preceding context and (2) type of following context. Each factor had two levels. The type of preceding context was either ambiguous or unambiguous. Unambiguous contexts contained verbs, such as 'wanted' and 'walked' that disambiguated the role of the word 'to', as in 4c and 4d. Ambiguous contexts contained verbs that can occur with the word 'to' functioning either as a preposition in a prepositional phrase complement or as part of an infinitival complement, as in 4a and 4b.[1]

(4)	a. The frustrated father hurried the kids to the school bus stop.	Preposition
	b. The frustrated father hurried the kids to get their lunch money.	Infinitive
	c. The frustrated father walked the kids to the school bus stop.	Preposition
	d. The frustrated father forced the kids to get their lunch money.	Infinitive

Processing load was assessed using a uni-modal, dual task technique that has been shown to be sensitive to the use of verb-specific information during reading. Clifton, Frazier, and Connine (1985) used the technique to measure processing load after the presentation of a word that was either consistent or inconsistent with the most frequently usage of a preceding verb. Verbs were those used most frequently with direct objects or those used most frequently without direct objects. Verbs were followed by noun phrase complements or prepositional phrase complements. The results showed that processing load was greater when the type of phrase indicated by the presented word was inconsistent with the most frequent usage of the preceding verb.

In the experiments described in this paper, the technique was used to measure processing load immediately following the onset of the word 'to' (Experiment 1) and the immediately following the onset of the "unambiguous" word in the prepositional phrase or infinitive (i.e., 'the' or 'get' in 4) (Experiments 2). If readers use prior sentence context to resolve the word 'to', as predicted by constraint satisfaction, then processing load following the onset of the word 'to' as well as following the onset of the "unambiguous" word should be greater when the preceding context is ambiguous than when the preceding context is unambiguous, as readers may generate and maintain both prepositional and infinitival complement analyses. If readers do not use prior sentence context to resolve the word 'to', as predicted by the delay hypothesis, then processing load following the onset of the word 'to' should not be influenced by the type of verb in the prior context. However, processing load following the onset of the "unambiguous" word should be influenced by the type of following context. Processing load should be greater when 'to' is disambiguated as being part of an infinitive than when 'to' is disambiguated as a preposition, as the former type of complement is syntactically more complex than the latter type of complement.

The Experiments

In Experiment 1, processing load was measured immediately following the presentation of word 'to' and in Experiment 2, processing load was measured immediately following the onset of the word immediately following the word 'to'.

Method

Participants. Ninety undergraduates at the University of Massachusetts participated for class credit. All had normal or corrected vision and were native English speakers.

Materials. Twenty verb triplets were created, each comprised of one verb that subcategorized for both a 'to' prepositional phrase complement and an infinitival complement, one verb that subcategorized only for a 'to' prepositional phrase complement, and one verb that subcategorized only for an infinitival complement. The verbs in each triplet were similar in length (+ 3 characters) and in printed frequency (assessed by Francis & Kucera, 1982). Two sentence frames were constructed for each triplet and were of the form NP VP NP PP or NP VP NP INF. The two sentence frames were identical until the determiner "the" or noun of the PP or until the verb of the INF. For each triplet, the first word to differ across the two sentence frames was matched for length and printed frequency. Lexical decision probes words were familiar nouns between x and x letters. The lexical decision probe words were paired with experimental sentences such that the probe word was not a plausible continuation of the sentence. A complete list of experimental sentences and the lexical decision probe words are provided in Appendix A.

Procedure. The experiment was controlled by an IBM compatible computer. Participants were tested individually in half hour sessions. They were told that they would see sentences presented word by word, on a video terminal, and that immediately after each sentence a TRUE/FALSE comprehension question would be presented. They were to respond by pulling a right trigger for true and a left trigger for false. In addition, somewhere during the presentation of each sentence, a single letter string would be presented at the far left of the video screen. The letters would be in uppercase and the whole string would be surrounded by asterisks. Participants were to indicate whether this string was or was not a real word by quickly pulling the right trigger for yes or the left trigger for no. The sentences were presented in an individually randomized order in a word-by-word fashion, 300 milliseconds per word with a 50 millisecond blank period after each word. Presentation was stopped

when a string was presented for lexical decision. As soon as the participant responded to the lexical decision word, presentation of the sentence was resumed. Eight hundred milliseconds after the end of the sentence, a question about the sentence was presented. After the participant responded to the question by pulling either the right or left trigger, the sentence "Press thumb key to continue." was presented. When the participants pressed the thumb key, operated by the right thumb, the next sentence was presented.

Experimental Design. A repeated measures design was used. The two factors were within-participants and had two levels.

Results

Reaction times and error rates to lexical decision probes were analyzed. In the analysis of reaction time, only correct responses were analyzed. Remaining reaction times that were either longer than 3 seconds or greater than 3 standard deviations from each participants' mean reaction time were eliminated from the data set. This trimming of the data eliminated less than one percent of remaining observations in both Experiments 1 and 2. All analyses of variance (ANOVAs) were conducted using participants (F_1) and items (F_2) as random effects.

Table 1 displays mean reaction time and error rates to lexical decision probes by type of preceding context and type of following context for Experiments 1 and 2. In Experiment 1, the lexical decision probe occurred immediately following the word 'to.' The analysis of errors rates across the four experimental conditions indicated that there was no significant effect of type of preceding context, $F_1(1,47) = 1.41$, $p < .24$, $F_2(1,19)=1.89$, $p < .19$, or type of following context, $Fs < 1$. The interaction between type of preceding context and type of following context was not significant, $Fs < 1$. The analysis of reaction times to lexical decision probes indicated that neither factor significantly influenced

reaction: the type of preceding context, $F_1(1,47)=1.57$, $p > .21$, $F_2(1,19)=1.28$, $p > .28$, and the type of sentence, $Fs < 1$. The interaction between type of preceding context and type of following context was not significant, $Fs < 1$.

In Experiment 2, the lexical decision probe occurred immediately following the disambiguating word. The analysis of errors rates across the four experimental conditions indicated that there was no significant effect of type of preceding context or type of following context, $Fs < 1$. The interaction between type of preceding context and type of following context was also not significant, $Fs < 1$. The analysis of reaction time to lexical decision probes indicated that participants responded faster in prepositional phrase conditions than in infinitive phrase conditions, resulting in a significant effect of type of following context, $F_1(1,47)=4.59$, $p < .04$, $F_2(1,19)=7.55$, $p < .02$. However, the effect of type of preceding context was not significant, $Fs < 1$. Furthermore, the interaction between type of preceding context and type of following context was not significant.

$Fs < 1$.

Discussion

Two reading experiments were conducted in which processing load was measured immediately following the word 'to' and an immediately following the disambiguating word in sentence contexts containing ambiguous or unambiguous prior contexts. The word 'to' was disambiguated as either a prepositional phrase complement or infinitival complement. The results of these experiments showed that processing load was affected only by type of following context. Readers responded more quickly when the word 'to' was disambiguated as a prepositional phrase complement than as a infinitival complement. Readers' responses were not affected by the type of preceding context. These results support the predictions of the Delay Hypothesis, which claims that syntactic category ambiguities, such

as the word 'to' in English, are left unresolved until following unambiguous context is encountered. The results do not support predictions of constraint satisfaction that claims that ambiguity is resolved using information from both preceding and following sentence context.

These results represent one of several studies showing that the resolution of syntactic category ambiguity is not influenced by biases stemming from the verb in preceding contexts. Kennison (1995) provides an investigation of the syntactic category ambiguity of the word 'that.' In English, the word 'that' can function as a complementizer (e.g., "Bill said that he had studied."), a demonstrative pronoun (e.g., "Bill said that."), and a demonstrative article (e.g., "Bill said that statement."). In four experiments, the word 'that' was preceded either by verbs that occur most frequently with sentence complements in which the word 'that' would function as complementizer or by verbs that occur most frequently with noun phrase complements in which the word 'that' would function as a demonstrative pronoun or demonstrative article. In these experiments, there was no evidence that the syntactic category ambiguity 'that' was influenced by the bias of the verb in the preceding context. In addition, Clifton, Kennison, & Albrecht (1997) investigated the syntactic category of the word 'her.' In English, the word 'her' functions as a pronoun (e.g., "They saw her.") or as a specifier (e.g., "They saw her friend."). In two experiments, the word 'her' was preceded either by verbs that occurred most frequently with human direct objects (e.g., "The supervisors persuaded her..."), by verbs that occur most frequently with inanimate direct objects (e.g., "The officials searched her..."), or by verbs that occurred equally often with human and inanimate direct objects (e.g., "The customers paid..."). The results showed that the word 'her' was not influenced the bias of the verb in the preceding context. These results are noteworthy because of the growing number of studies showing the verb bias can influence how readers resolve structural ambiguities (Garnsey et al., in press; Holmes, Stowe, &

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Cupples, 1988; MacDonald, 1994; Trueswell, Tanenhaus, & Kello, 1993). The most straightforward implication is that verb bias may influence how comprehenders resolve different types of ambiguities differently.

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Appendix

The following is a list of experimental sentences used in Experiments 1-2. The lexical decision probes are provided in parentheses. There are four versions of each item: (a) ambiguous verb-prepositional phrase complement; (b) ambiguous verb-infinitival complement; (c) unambiguous verb-prepositional phrase complement; (d) unambiguous verb-infinitival complement. The '*' indicates the position of the lexical decision probe in Experiment 1 and the '@' indicates the position of the probe in Experiment 2.

1.(a) The secret service agents reported the intruder to* the @ chief administrator. (b) The secret service agents reported the intruder to* be @ quiet during the interrogation. (c) The secret service agents relayed the intruder to* the @ chief administrator. (d) The secret service agents advised the intruder to* be @ a terrible hoax. (AREA)

2. The farmers returned the workers to* the @ fields after lunch. (b) The farmers returned the workers to* do @ the plowing and planting. (c) The farmers referred the workers to* the @ unemployment office. (d) The farmers permitted the workers to* do @ the plowing and planting. (ITEM)

3. (a) The doctor helped the patient to* the @ bed. (b) The doctor helped the patient to* go @ to the specialist. (c) The doctor referred the patient to* the @ specialist. (d) The doctor forced the patient to* go @ to see a specialist.(CHARM)

4. (a) The frustrated father hurried the teenagers to* the @ school bus stop.(b) The frustrated father hurried the teenagers to* get @ money for their lunch. (c) The frustrated father walked the teenagers to* the @ school bus stop (d) The frustrated father forced the teenagers to* get @ money for their

lunch. (TOAD)

5. (a) The President sent the ambassador to* the @ peace conference. (b) The President sent the ambassador to* see @ Russian leaders.(c) The President exposed the ambassador to* the @ peace conference. (d) The President urged the ambassador to* see @ the Russian leaders.(SOCK)

6. (a) The older kids enticed the boy to* the @ bars on the weekend. (b) The older kids enticed the boy to* go @ to bars on the weekend.(c) The older kids exposed the boy to* the @ bars on the weekend.(d) The older kids pressured the boy to* go @ to bars on the weekend.(WALL)

7. (a) The people elected experienced politicians to* the @ state legislature.(b) The people elected experienced politicians to* go @ to the state legislature. (c) The people recommended experienced politicians to* the @ state legislature. (d) The people persuaded experienced politicians to* go @ to the state legislature(MULE)

8. (a) The probation officer described the gang leader to* the @ judge. (b) The probation officer described the gang leader to* be @ a better person. (c) The probation officer participated the gang leader to* the @ therapy. (d) The probation officer caused the gang leader to* be @ a better person. (HEALTH)

9. (a) The Colonel assigned the recruit to* the @ cleaning detail. (b) The Colonel assigned the recruit to* get @ more paint for the barracks. (c) The Colonel recommended the recruit to* the @ cleaning detail. (d) The Colonel enlisted the recruit to* get @ more paint for the barracks. (POET)

10. (a) The harbor police directed the deep sea divers to* the @ cables of the ship. (b) The harbor police directed the deep sea divers to* go @ to the sinking ship. (c) The harbor police attached the deep sea divers to* the @ cables of the ship.(d) The harbor police enabled the deep sea divers to* go @ to the sinking ship. (CENT)

11. (a) The governor nominated the banker to* the @ committee. (b) The governor nominated the banker to* be @ the committee chairman.(c) The governor introduced the banker to* the @ committee.(d) The governor encouraged the banker to* be @ the committee chairman.(YEAR)

12. (a) The talent agent committed the actor to* the @ production of the play. (b) The talent agent committed the actor to* be @ lead actor in the play.(c) The talent agent introduced the actor to* the @ director of the play. (d) The talent agent instructed the actor to* be @ lead actor in the play. (FOOD)

13. (a) The judge ordered the convicted woman to* the @ state prison. (b) The judge ordered the convicted woman to* be @ at the next trial on time. (c) The judge delivered the convicted woman to* the @ state prison. (d) The judge expected the convicted woman to* be @ at the next trial on time.(IDEA)

14. (a) The charming con artist invited women to* the @ hotel for drinks. (b) The charming con artist invited women to* see @ the view from his hotel room.(c) The charming con artist delivered women to* the @ hotel for drinks.(d) The charming con artist convinced women to* see @ the view from his hotel room.(HOUR)

15. (a) The young couple trusted the children to* the @ teenage babysitter. (b) The young couple trusted the children to* be @ well behaved for the teenage babysitter.(c) The young couple defended the children to* the @ teenage babysitter.(d) The young couple prepared the children to* be @ well behaved for the teenage babysitter.(GOAL)

16. (a) The general appointed the soldiers to* the @ recruiting branch of the army. (b) The general appointed the soldiers to* get @ more recruits for the army.(c) The general defended the soldiers to* the @ recruiting branch of the army.(d) The general inspired the soldiers to* get @ more recruits for the army.(CAKE)

17. (a) The boys asked the girls to* the @ dance. (b) The boys asked the girls to* to @ dancing. (c) The boys defended the girls to* the @ principal. (d) The boys told the girls to* go @ dancing. (CRANE)

18. (a) The accountant summoned the secretary to* the @ conference room. (b) The accountant summoned the secretary to* see @ conference room.(c) The accountant identified the secretary to* the @ conference organizers.(d) The accountant inspired the secretary to* see @ the conference room.(WEEK)

19. (a) The guidance counselor drove the sick student to* the @ doctor's office.(b) The guidance counselor drove the sick student to* see @ the doctor. (c) The guidance counselor added the sick student to* the @ doctor's appointment book. (d) The guidance counselor advised the sick student to* see @ the doctor.(SONG)

20. (a) The lawyer called the witness to* the @ stand to testify. (b) The lawyer called the witness to* say @ what she had seen.(c) The lawyer added the witness to* the @ list provided to the judge.(d) The lawyer permitted the witness to* say @ what she had seen.(PAIN)

Author's notes

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Footnotes

[1]The word 'to' in English may also occur in prepositional phrases and infinitival phrases that do not play a central role in the meaning of the sentence. Such phrases have been referred to as adjunct phrases. Complements, in contrast, do play a central role in the meaning of the sentence. Complement and adjunct phrases are claimed to differ not only in terms of their meaning roles in sentences but also their syntactic structure in sentences. The sentences used in Experiments 1 and 2 were constructed to ensure that adjunct phrases were unlikely to occur.

Table 1. Reaction time in ms (% errors) to lexical decision probes in Experiments 1 and 2.

Experiment 1: Probe Occurred Following the Word 'to'

	Type of Following Context		
Type of Preceding Context	PP	INF	Mean
Ambiguous	1051 (4%)	1024 (4%)	1038 (4%)
Unambiguous	1025 (7%)	1008 (5%)	1017 (6%)
Mean	1038 (6%)	1016 (5%)	

Experiment 2: Probe Occurred following the Disambiguating Word 'the' or 'get'

	Type of Following Context		
Type of Preceding Context	PP	INF	Mean
Ambiguous	973 (5%)	1012 (3%)	988 (4%)
Unambiguous	992 (3%)	1014 (5%)	1003 (4%)
Mean	983 (4%)	1013 (4%)	